# Innovative Application of Scientific Facts for Reducing Methane Emission and Enhancing Productivity of Paddy Fields

## A Generation II Agriculture Decision Support Conceptual Model

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***Abstract***

This study was carried out with objective to devise innovative universally applicable manifestations in the forms of practices to reduce the methane emission and increase the productivity of paddy fields on the basis of application of knowledge of sulphur cycle and other environmental engineering principles. The study resulted in development of a conceptual model for decision supporting for paddy culture comprising manifestations of practices in domain of cropping system, cultural practice, nutrient supplementation and additional methane eradicative measures. The crux of the finding is to convene decompositions along aerobic path of sulphur cycle. With the support of the model a zero methane emission and yield plateau breaking universal applicable paddy culture was composed. Researches on factor optimization involved in the culture and worldwide initiative on its application will go long way in reducing methane emission and enhance productivity of paddy fields.

***Keywords***

*Decision Support Conceptual Model; Food Sufficiency Triggered Socio-political Stability; Global Warming; Paddy Field Productivity; Sulphur Cycle and Zero Methane Emission*

## Introduction

Rice is major food crop for the world to feed at least 50% of the global population. The land resources for new rice field are almost exhausted in most rice growing areas. **IRRI IRRI, 1995** estimated that world's annual rice production must increase from a 1990 value of 473 million tonnes to 600 million tonnes by 2010 to meet the increasing demand of population world over. As quoted by ***Aulakh* et al. (2000**), **Sass et. al., 1999** estimated that in South Asia the rice production must double by the year 2020 to match the requirement of increased population. Therefore, intensive cultivations of rice were to be resorted to with increased irrigation facilities. The suggested rice intensive production measures were double and triple crops of rice using early maturing rice varieties, which involved cropping systems. The other measures of crop production suggested by ***Aulakh et al*, (2000)** were, soil tillage, puddling, cultural operations such as weeding, prolonged soil submergence, planted periods, as well as the greater inputs of nutrients.

The rice fields are also known to be important sources of methane emission, estimated between 60-150 Tg/year (**IPCC, 1992**, 1Tg= $10^{12}$ g). With the rice intensification and increase in the submerged paddy fields, the problem of methane emission will increase adding more methane to the atmosphere.

The prolonged flooding of the paddy fields restricts oxygen diffusion to soil and after some time of planting, it leads to the anaerobic decomposition of organic matters. The anaerobic biochemical reaction produces $CO_2$, $H_2S$ and $CH_4$. These reactions are well understood and applied in the environmental engineering applications, but rarely employed in processes dealing with decomposition associated to nutrients in agriculture. The resulting benefits of such process of decompositions are referred to in the exhaustive article presented by ***Aulakh* et. al. (2000).** However, there existed lack of explicit display of the application of sulphur cycle. **Yadav (2012)** elaborated in detail the decomposition involving situations in waste water streams and agriculture in general. In addition to those, this study further elaborates the situation of application of the scientific facts with respect to practices for paddy, in particular, with respect to crops, cropping system, nutrient supplementation and additional methane emission reduction methods etc.

So far the anaerobic reaction assumed to release the methane, another hazardous gas emanating from the reaction ie hydrogen sulphide ($H_2S$), equally dangerous to plants, got over looked. The $H_2S$ is soluble in water. It moves with water to wells and causes lot of other problems such as fatality in wells, sewers and storage tanks (**Yadav et. al. 2008).** Irrigation with sewage water lends quick formation of $H_2S$ and creates sewage sickness in salty soil. The $H_2S$ is injurious to plants that produces remarkable reduction in yield of crops in general and paddy in particular, if and where, cellulose anaerobic decomposition get involved during nutrient supplementation etc. First objective of the study was to further substantiate the knowledge gap on application of very appropriate scientific fact of sulphur cycle in paddy cultivation, which remained blamed for voluminous release of the methane to the atmosphere (**Wuebbles and Tamaresis**, **1993)**. The second object of the study was to apply the manifestation of the scientific fact of sulphur cycle in devising innovative practices of universal applications in the domain of the crops, cropping practice, operation, nutrient supplementation and reduction in emissions of methane and accompanying gas $H_2S$ to make the practices effective and productive. Using the scientific facts of sulphur cycle, nitrogen cycle, and absorption principles of environmental engineering and verification by the experimental results from the reviews a decision support conceptual model was devised and prescription of practice designated as zero methane emission paddy culture was prescribed. Such practices will help break rice yield barrier, increase land resource, nutrient and water use efficiency and reduce burden of methane, thereby, lessen the world wide worrisome problem of global warming.

The manuscript is devoted to presentation of the sulphur cycle, substantiation of the utility of application of knowledge of sulphur cycle etc., its application and manifestation of the scientific facts for devising universally applicable paddy culture with additional measures for eradication of the methane to reduce atmospheric burden. Further, it includes a conceptual decision support model useful in deciding components of zero methane emission paddy culture. Based on the study meaningful conclusions are presented and specific research needs are chalked out for promoting paddy culture and reducing emission and increasing efficiency of resources use. It is expected that when the results of the research studies in the specified areas are applied, it will bring food sufficiency and lessen the global warming. The resulting food sufficiency will lead to fulfilment of primary needs (Physiological) and socio-political stability world over.

## The Scientific Fact

The decomposition of cellulose reduces to sulphate or sulphide by aerobic and anaerobic condition respectively **(Fig 1).** During the aerobic decomposition the sulphur content of residue gets converted in to sulphate **(Lovely and Klug, 1983)**, which is directly taken up by the plants for promoting growth. The sulphur, taken in sulphate form, is a constituent of amino acids such as cysteine, cystine and methionine involved in chlorophyll production, which is required for protein synthesis, plant function and structure. Effect of sulphate is significantly affected by sulphur available doses **(Cimrin et al., 2008).**

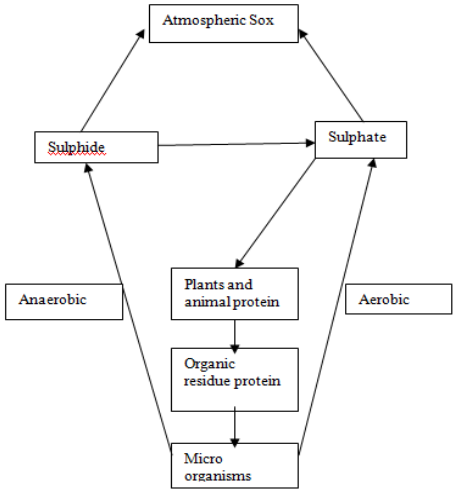


FIG. 1 SULPHUR CYCLE (after De, 2004)

On the other hand, the anaerobic reaction occurs under prolonged flooding in lowlands, following irrigation and rain and produces hydrogen sulphide, methane and carbon dioxide. The hydrogen sulphide is inimical to plants. The benefits that results due to operation of sulphur cycle have been realized, but results have hardly been reasoned scientifically. The knowledge of sulphur cycle (**De, 2004,**) needs additional emphasis in devising practices of universal application of such management of waste and residues in agriculture.

A physico-chemical process developed to transform and enhance lingo cellulosic waste in liquid humic extracts: humic-like substances (HLS) (**Eyheraguibel et al., 2008**), showed that HLS do not increase the percentage and rate of germination. But, it enhances

the root elongation of seeds, thus treated. Plant growth as well as root, shoot and leaf biomass were positively improved. These effects can be related to the high water and mineral consumption of plants undergoing this treatment of HLS. The high water use efficiency indicated that such plants produce more biomass than non-treated plants for the same consumption of the nutrient solution. Furthermore, the use of HLS induced a flowering precocity and modified root development suggesting a possible interaction of HLS with developmental processes. **Ayes et.al, (1996)** showed that HLS derived from sewage sludge and other chemical formulation were equally effective. N uptake was better at lower concentration of HLS and P and other micronutrients were enhanced at higher concentration.

The anaerobic decomposition is convened as pre treatment of heavily loaded waste material of sludge or refuge from extensive waste producing industries, a mandatory requirement in many countries, for disposal of industry waste water in to municipal waste water disposal systems. The principle of anaerobic decomposition is utilized in dung gas plants, where methane is produced and recovered for heat energy and digested dung slurry discharged for further uses such as composting and vermin composting. However, due to limitations of burning efficiency of the methane and unpleasant scenes and need of extensive repairs of dung digester plant make the dung gas plants less attractive after some years of use.

### *The Nitrogen Cycle*

Atmospheric nitrogen is captured and stored in soil by nitrogen synthesizing bacteria under aerobic condition which is useable by crops. Many forms of such practices are in vogue for upland agriculture, but rare for submerged paddy fields. The use of nitrogen cycle has to be made by devising cropping system for pad culture during the periods land remain under aerobic condition. The anticipated beneficial effects of recovered material/ mass from the waste streams when get converted in the form of anaerobic compost do not bring desired beneficial effects. The situation gets worsened for irrigation with sewage water or salty water or in saline alkali soil bring the bad effect of sewage sickness. The sewage sickness restricts air circulation that produces hydrogen sulphide, known for many harmful effects **(Yadav et al., 2008).** Sulphur accumulation by anaerobic decomposition of organic wastes left by weeds that grow in wet lands ecosystems may cause acidity in future **(Jngshuang and Xinhua, 2008).**

### *Adsorption and Absorption Principle of Environmental Engineering*

Existence of methane and sulphur dioxide is also toxic gaseous pollutants in liquid or air. There can be suitable manifestation to absorb the methane and hydrogen sulphide gases to reduce burden of releases from the paddy fields to the atmosphere. Charcoal, which has enhanced surface area due to containing pore spaces, is known to adsorb salt and impurities and absorb toxic gases in liquid or air. Utilizing these characteristics many environmental applications are devised.

## Substantiation of Knowledge Gap

### *Substantiation*

The organic manures, be directly incorporated in field or as a part of amendment through manure of different kinds, contain cellulose and plant tissues in dried form. Trends of researches in various domains where it involves application of scientific fact of sulphur cycle were described in another study presented by **Yadav (2012)**. It was evidently substantiated that although benefits of process of decompositions were realized, the real scientific basis for explanations of the reasons were not adequately visualized and displayed. Thus, it can be said that there existed some knowledge gap. Further, substantiation of the fact of knowledge of sulphur cycle, particularly applied to paddy, is made in support to the fact of situation.

Table 1 contains some specific details of the fact of gap in application of sulphur cycle in devising practices for the paddy culture. The review presents exhaustive and extended knowledge on the factors involved in paddy culture responsible for emission of enormous volume of methane to the atmosphere. The review focused on extra knowledge that involved use of crop varieties and characteristic factors that are controlling methane emission from paddy fields. In order to supplement food production to cope up with large food requirement of the global population **Aulakh et al.,2000** recommended double and triple crops of paddy per year. However, cropping pattern and crop rotation play important role in enhancing crop productivity (**Acharya et. al. 2008 and Yadav, 2012**) that implicate double and triple crops of paddy per year.

TABLE 1 SUBSTANTIATION OF STATUS OF USE OF THE SCIENTIFIC FACTS OF SULPHUR CYCLE IN PADDY CULTURE FOR ENHANCING CROP PRODUCTIVITY AND REDUCING EMISSION OF METHANE FROM PADDY FIELDS.

| S.No. | Items of consideration of production function and release of methane | Status of application of scientific facts of sulphur cycle in paddy field | Inferences drawn in support of the scientific justifications. | References |
|---|---|---|---|---|
| A. | **Paddy crop variety for multiple cropping** | | | |
| 1 | **Use of short duration crops to carry out double and triple crop of paddy per year** | Same crop year after year may not be suitable without any suitable crop rotation. Methane production was found proportional to above ground biomass production Cultivars performing better under aerobic condition will emit less methane than anaerobic decomposition. | It involved crop breeding, agronomical knowledge, plant physiology and no direct application of the sulphur cycle. However, more biomass production is related to tissue and growth development which are produced under aerobic condition. Therefore, results contravene the aerobic decomposition and uptake of sulphates. These studies should have recorded higher yield levels but for the sulphide effects the yields were low. Net effect of cultivars was not scientifically explainable and recommended more evaluation. The crop growers may not care for crop variety for reduction of methane, as there will be craze for high yield. The cultivation and paddy culture practice producing high yield may be acceptable that may indirectly reduce methane emission from the paddy fields. | Sass et.al. 19993, Wang et.al.,1990, Zhang et.al. 2009. |
| 2 | **Root exudation** | Biomass and dead substances get decomposed | Occurs during tillering and flowering occurs due to extensive root exudation | Lu et al.,1999 |
| 3 | **Rice root exudates and decaying tissues** | Dead tissues and cellulose follow the decomposition law of sulphur cycle. | Plant biomass drives root exudation | Sass et al, 1993 |
| B | **Cropping patterns** | | | |
| 1 | **Suggestion for any suitable cropping pattern and cropping system** | No visible emphasis laid in the review and referred articles | Knowledge of sulphur cycle helps devise suitable cropping pattern and cropping systems. | Achary et al, 2008,Yadav et al,2011 |
| C | **Effect of type of Paddy soils** | | | |
| 1 | **Intrinsic methane production potential** | $CH_4$ production potential of soil is an important component for understanding site to site variation of global methane production. | Methane production potential varies several orders of magnitude. Temporal pattern of $CH_4$ production pattern over 6-8 weeks appear to be more reliable criteria for classification of as compared to average rate which varies with the study. | Wang 1992 Wassman et al 1993 |
| 2 | **Amendments** | Soils high in added carbon content and added nitrogen content are supposed to release more methane due to anaerobic decomposition | Results were confirmatory to those revealed by the sulphur cycle. Soil temperature at 5 cm depth was different under different agronomic practices that released more methane. However, some soils were found to decrease methane at temperature > $35^0$C.Contrasting temperature values were reported. | Wassman et.al.,1989, Parasher et al ,1993. |
| 3 | **At higher Eh** | - | The increase in temperature escalates reducing efficiency Eh so $CH_4$ emission drops. This result is as per the sulphur cycle. However, no indication of its implication was found. Soil anaerobiosis, measured in terms of redox potential (Eh) ranging from -100 to-200mV has been reported to be initiation of $CH_4$ production in paddy soil. | Wassman, 1998, Wang et al, 1993. |
| 4 | **pH** | Methane production in reduced soil is very sensitive to pH with an optimum ranging from 6.7-7.1 that varies with soil type. | Flooding of soil causes soil pH to stabilize between 6.5 and 7.2, which is the optimum range for $CH_4$ production. | Ponnmperuma, 1972. |
| 5 | **Soil drying** | Soil drying was found to increase cracks that enhanced $CH_4$ emission; especially for fine soils. | About 10% of the methane released by the entire season of rice crop is released during drying after harvest. However, this may not happen with other soil that remain submerged or ploughed immediately after harvest of rice crop. | Denier van der Gon et, al.1996 |
| 6 | **Soil texture and $CaCO_3$** | | There occurs negative correlation between $CH_4$ emission and clay content. Seasonal $CH_4$ emission of 220.1 and 36.1 g/$m^2$ were from the fields with 66 and 21% clay, respectively. On the other hand, calcareous soil showed | Sass et al. 1999, Denier, van der Gon 1996. |

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|---|---|---|---|---|
| | | | rapid formation of $CH_4$ upon flooding. Higher clay can entrap $CH_4$ and consequent reduce net $CH_4$ emission. Peat soil releases highest $CH_4$ emission | |
| 7 | **Soil salinity** | A soil is called saline if electrical conductivity of saturated extract exceeds 4 $dSm^{-1}$ | Predominant anions in saline soils are chloride, sulphate and carbonate. Sulphate reducing bacteria in the presence of sulphate could out compete methanogensis for substrates, the $CH_4$ emission is reduced. A correction factor is needed for global emission estimate from the saline soil. | USDA,1954, Denier van der Gon et. al,1996. |
| **D** | **Seasonal and diurnal variation** | | | |
| 1 | **Diurnal variation** | _ | Poor or no correlation was found. Early or late paddy crops have diurnal variability of $CH_4$ emission. On clear sky day more $CH_4$ emission occurred afternoon. | Satpathy et al.1997, Dernier vander Go et.al. 1996, Wang et al 1994. |
| 2 | **Seasonal variation** | Added compounds take time to start decomposing and get fully utilized for decomposition after some time. | In the beginning of planting seasonal emission goes at slow rate. And increases at other growth stage of tillering and flowering and drops at harvest. Most of added organic compounds get decomposed after wards, which is as per the sulphur cycle. | |
| **E** | **Cultivation** | | | |
| 1 | **Up land , rain-fed and irrigated** | Alternate wetting and drying (AWD) save irrigation water. Except in few studies, aerobic rice is known to give yield loss, by 40-50 % of yield of submerged field paddy yield. | Only in few studies the aeration of the soil was of concern. However, there was no specific application of scientific fact of sulphur cycle. Up land paddy releases lower methane than the submerged paddy. This finding supports the sulphur cycle, but no mention of this fact was observed. Cropping pattern plays important role, many crops absorb more sulphate and produce high yield of crop in the crop rotation/ cropping pattern | Acharya et al 2008. |
| 2. | **Wet land submerged field paddy cultivation** | Some studies have found submergence very essential for getting high paddy yield | Occurrence of anaerobic decomposition was accepted but, development of $H_2S$ was not visualized. Knowledge gap of sulphur cycle led to faulty design of experimental study leading to contradictory results. | Singh et al, 1977 |
| 3 | **Deep water Paddy** | Deep water comprising large proportion of oxygen enables aerobic decomposition leasing to low emission of methane. | Results were correct, but no explanation was found. | Aulakh et. al., 2000. |
| **F** | **Operation** | | | |
| 1 | **Primary tillage** | Submerged paddy cultivation in puddle field provoked to have advantage of soft ground for planting, creating solid subsurface layer for reducing deep percolation of standing water | Creates anaerobic condition for some time after planting in excessively churned puddle/plowed soil. The Additional dissolved oxygen in puddle soil and water supports aerobic digestion of cellulose and organic substances as depicted by the sulphur cycle, was not visible anywhere in the culture suggested in the two decades of research. | Aulakh et al.2000 |
| 2 | **Eradication of $H_2S$** | $H_2S$ is produced in anaerobic decomposition of cellulose as revealed by sulphur cycle. | This hazardous gas was not found in the review and article published in literature | Aulakh et. al., 2000 |
| 3 | **Secondary tillage** | Puddling and weeding are known to induce diffusion of oxygen in soil and water that promotes aerobic action thereby, reduction in release of methane from the submerged paddy field | This benefit has been documented. However, no mention and correspondence of sulphur cycle was made to support the scientific reason. | Aulakh et al., 2000 |
| **F** | **Nutrient and fertiliser supplementation** | | | |
| 1 | Inorganic nitrogen | As per anaerobic decomposition $CH_4$ emission should increase. However, through ammonium sulphate the efficiency of N use is increased and methane release should decrease. | The results were confirmatory to that revealed by the sulphur cycle. Aerobic decomposition promotes sulphate formation. At low concentration, the sulphate promotes uptake of N and at higher concentration it promotes uptake of P and K. However, working of sulphur cycle was not mentioned in the scientific explanation of the phenomena. $CH_4$ emission was proportional to nitrogen applied $NO_3$ as N source should be good mitigation option for reducing $CH_4$ emission, without reducing yield. | Schulz et al, 1989, Lindau et.al.1993 |

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|---|---|---|---|---|
| 2 | Phosphorus | Uptake increases at high concentration of sulphate. | $CH_4$ emission should reduce. But, the results were contradictory. However, use of sulphur cycle was not found. P stress causes higher root exudation. | Adya et al 1997, Lipton et al., 1987, Lu et al. 1997 |
| 3 | **Other nutrient. K potassium.** | $K_2SO_4$ under aerobic de-composition promotes K up take and suppresses $CH_4$ release | Finding of $K_2SO_4$ supports sulphur cycle. However, the review did not make any mention of sulphur cycle. Increase in methane release was found with non sulphate K fertilizers, such as KCL> $K_2HPO_4$. | Wassman et al.1993a, 1993b, Adya et al, 1997. |
| 4 | **Other micronutrients, Zn, Mo, $NO_3$-reductase,** | – | Stimulate Methane release in pure culture of nitrogenate and $NO_3$- reductase. And in anaerobic digester. Copper Co and Boron B. have been reported to convert acetate to $CH_4$ by methanogens. Nickle Ni, is a constituent to urease co enzyme $F_{430}$, $F_{420}$ reducing hydrogen and methyl reductase, Mo, Ni and B had more pronounced effect than Zn, Fe and Co. There is dose specific optimum production of methane. Micro nutrients Fe and Mn showed distinct inhibition of $CH_4$ production in soil at 50 mg Fe $CL_3$ kg-1and 10 mh Mn Cl2Kg-1soil.,respectively.. Various micronutrients at low concentration could enhance $CH_4$, where as Fe and Mn if present in higher concentration would inhibit methano-gensis in paddy soils. | He et.al., 1989. |
| G | **Inhibatory effect of Sulphate** | | | |
| 1 | **$(NH_4)_2$ $SO_4$ and Ca $SO_4$** | These sulphatic fertilizers are found to reduce the release of $CH_4$. | Proved suitable for reducing $CH_4$ emission at higher concentration. However, sulphur cycle was not brought in picture to support the scientific cause of the reaction. | Adya et al., 1997. |
| 2 | **Gypsum, Ca $SO_4$** | Is most common soil amend-ments used for reclaiming sodic and/or alkali soil for rice cultivation. | As per sulphur cycle correction factors may be necessary for estimating the $CH_4$ emission from flooded rice fields on soils naturally high in sulphate or soil amended with large amount of sulphate contaning substance such as gypsum. | Abrol et al., 1985. |
| 3 | **Methane inhibitors.** | Calcium carbide | Calcium carbide is very effective in inhibiting gaseous methane from flooded rice. | Bronson and Mosier 1991. |
| H | **Organic manures and crop residues** | | | |
| 1 | **Compost** | Ordinary compost increases methanogensis | The fact is realized but working of sulphur cycle is not corroborated for explaining the scientific fact. NADEPED composting is known to reduce emission of the methane from composting practice. | Yadav, 2012, Freney et al 1982. |
| 2 | **Green manuring** | More readily available green manures have strong content of N and organic matter. | Green manuring crops such as cow pea and the Sisbania aculenta, L) can be grown for 45-60 days, during May to June when fields are vacant after wheat. Application of 12 tonnes GM stimulates $CH_4$ emission several fold. Methane emission was four times higher from green manure than urea fertilized plot. Pig manure emitted 1300 and green manure 2000mg $CH_4/m^2$/day-1 | Buresh and de Datta., 1991, Demier van der Gon et.al.199, Lauren et.al., 1994, 2006.Ping et al.,2007. Shah et al,2011, Singh et al.,2008 |
| 3 | **Crop residue** | Anaerobic decomposition produces methane flux. | This decomposition goes as per sulphur cycle. However, no mention of sulphur cycle appeared in the study. Application of paddy straw before planting and ploughing under aerobic condition produces $CH_4$ flux. Decomposition of rice straw by composting before incorporation reduced methane emission by 20%. Rice straw applied plot intermittently irrigated had no release of methane from sandy soil due percolation losses in northern India. | Corton et al, 2000. Jain et al, 2000.,Ping et al. 2007. |
| | **Water management** | | | |
| I | **Water management** | AWD is known for water saving and supply of $O_2$ that reduces $CH_4$ emission. | This result as per occurrence of the sulphur cycle with aerobic decomposition. Percolating water transport beyond the methanogensis depth that reduces methane flux from the soil. Intermittent drainage was found to increase water use and increased methane release. The sulphur cycle was not visualized although the results were visualized. | Wang et al.,1992 Sandhu et al.,1980. Jha et al 1981. Liping et al.,1987, Quanki et al, 2007 |

It is well known fact that the fixed resources such as land and to some extent even availability of ware in global domain, should have targeted use (**Yadav, 2012**). Research efforts in last two decades (**1980-2000**) revealed progressive knowledge on intricacies of paddy culture on environment deteriorating problems. The exhaustive reviews presented in the past comprised various aspects such as effect of soil types

and associated factors, intrinsic, amendments, soil pH, Eh, alkalinity, salinity on the emission of methane from the paddy fields **(Aulakh et. al., 2000)**. The operational factors studied were primary tillage, secondary tillage, weeding, puddling etc those are involved during paddy cultivation. Effect of nutrient supplementations, chemical measures, irrigation and drainages practices that favor reduction of methane emission from the paddy fields and those known to enhance productivity of paddy fields are enumerated. These are the topics of current research on this subject even in 21st century (**Singh et al. 2003, Tasneem et al, 2011** and **Wassmann et al., 2009**). There has been lack of scientifically innovative approach in general. Refinements on the mechanism of emission of methane (**Xu et al,2000**), estimate of quantity from countries and use of sulphate (**Saengen et al., 2012**) and water management (**Wassmann et al., 2009** ) are the recent approaches to continue.

Agenda for negotiation in Copenhagen for Food, Agriculture and the Environment on Reducing Methane Emissions from Irrigated Rice (Wassmann et al., 2009) suggested further reading on advancements viz. greenhouse gas mitigation: issues for Indian

TABLE 2 STATUS OF GOALS AND LIKEY IMPROVEMENT THAT WOULD HAVE COME THROUGH INNOVATIVE APPLICATIONS OF SCIENTIFIC FACTS OF SULPHUR CYCLE.

| | Desired goals to reduce methane emission | Correspondence of results from sulphur cycle | Remarks for improvement |
|---|---|---|---|
| **A** | **Strategy for methane emission reducing goals** | | |
| 1 | **Maintaining or increasing rice yield.** | The application of sulphur cycles displays the better utilization of nutrient, water and soil resources to enhance yield of paddy where organic and cellulose decompositions go side by side. | Most of research efforts were devoted in identification of factors as detailed in **Table 1** |
| 2 | **Finding additional benefit to the farmers such as better water utilization and reduction of labours.** | Application of principle of sulphur cycle leads to better resources, water and nutrient use efficiency | Research efforts did not move ahead of factor identifications. |
| 3 | **Identifying rice varieties desirable to local consumers.** | The breeding of suitable crop varieties that reduce methane and produce quality and enhanced crop yield is long term process. Users can not wait for such varieties and would go for any variety available to them for the preferred quality and yield | By the time some long term measures take the ground, the situation would have changed so technology and research gap remains almost all the time. |
| 4 | **Decreasing/maintain rather than increasing the emission of other green house gases, such as $N_2O$** | Application of sulphur cycle is capable to guide selection of practices that would reduce/eliminate $N_2O$ green house gas. | The decomposition process does release another poisonous gas that causes fatality in well and even while remaining in paddy field becomes injurious to crop plant could not come to notice of researchers. $H_2S$ would have played detrimental effect on holding yield growths and betterment in the quality of paddy crops. |
| **B** | **Abatement Strategic goals** | | |
| 5 | **Direct seeding of paddy crops** | Weed infestation and low tillering of paddy seem discouraging. Yield losses are unavidable (Yadav et al., 2011.) | The practice may be followed under compulsions of water and labour scarcity and inhibitive cost. But yield losses are unavoidable. |
| 6 | **Mid season drainage to convene oxygen diffusion in soil for promoting aerobic decomposition.** | With the time paddy growing areas are suffering phenomenal decrease in water table. At the tillering and flowering time famers hesitate to drain the water from the field for the sake of reducing release of methane. | The recommendation is not palatable to water scarcity regions. Some other innovative application of scientific fact is warranted. |
| 7 | **Composting of organic and cellulose material as amendment** | Composting is not very specific. The prevalent practice of composting, particularly in India release methane which counterfeit the fulfillment of desired goal | Aerobically decomposed composting, popularly known as NADEP composting (Yadav, 2012) is appropriate .But it could not be figured out in the study. |
| 8 | **Supply of NPK nutrient through sulphate containing fertilizer and amendment gypsum to reduce $CH_4$ emission from paddy fields.** | Although principally it is correct to apply sulphate comprising fertilizer, But availability and cost factors prevent one to be able to follow the recommendation | Lack of knowledge of innovative application of the sulphur cycle could not enable devising innovative practice to fulfil the set goal of researchers. |
| 9 | **Zero tillage and mulching to mitigate methane emission** | After harvest of paddy drying of soil emits 10 % of seasonal emission of methane during the cropping season. Maintenance of aerobic decomposition after harvest of paddy would be the best. This scientific fact now casts doubt on utility of zero tillage and mulching with regard to reduction of methane emission and enhancing yield of following crop of wheat. | Contrary to let sulphur cycle function to bring reduction in methane emission/ |

agriculture*(Nelson et al, 2012)*, greenhouse gas emissions from Indian rice fields: calibration and upscaling using the DNDC Model ( Pathak et al,2005), sequestration potential of top soil organic carbon in China's paddy soils( Pan et al., 2003), estimations of the inventory and mitigation potential of methane emissions from rice cultivation conducted using the 2006 IPCC Guidelines (Yan et al, ) and statistical analysis of the major variables controlling methane emission from rice fields (Yan et al.,2005).

Another study by **Yadav 2012** covered period after year 2000 till the recent time accounted period more than one decade, revealed that although benefits of decomposition of organics and cellulose had been realized, real scientific facts were inadequately visualized and displayed. In this study, it was possible to draw the instant conclusions by application of sulphur cycle that could be drawn after long period of research. Nevertheless, the review enabled substantiation of validity of application of sulphur cycle in chemical process that function in the paddy fields. This enables bring further advancement in devising ways and means of universal application for reducing methane emission and enhancing paddy field productivity. This developmental study substantiated the facts applicable for paddy culture. The research guide lines devised by S**ass, et. al., 1999** were compared with innovative facts revealed by the reviews.

### *Status of Application of the Scientific Knowledge*

Methane emission from the paddy field is a microbial process and is affected by factors of soils, rice ecosystem, environment and management factors. The sulphur cycle takes good account of factors of cellulose decomposition. Anaerobic decompositions of organics are well understood in environmental engineering. The application of both microbial processes to understand and devise strategic measures should go side by side. A comparison of mitigation options devised by **Aulakh et al 2000** in their esteemed published review and status of this research on the advances in the methane emission and paddy field productivity are drawn in T**able 2.**

### *Source Strength, Paddy Ecology and Mitigation*

The insufficiency in application of scientific facts of sulphur cycle resulted in discrepant practices that could not fulfil the set goals for paddy culture. These facts are substantiated by the facts depicted in **Table 2**. The preventive goal factors are found relatively of lower scientific merit than the reductive strategies. Occurrence of this fact is obvious, as the natural processes of water and environment in the submerged paddy fields will occur and cannot be stopped. Since these preventive practices suffer severe setbacks of attracting users' preference for ongoing paddy culture that are bound to produce methane emission in paddy fields. The adverse effect of such unsuitable practices can be ameliorated by innovative application of scientific facts of sulphur cycle and nitrogen cycle etc. Thus, there is need to devise manifestations of sulphur cycle of strong effect and adopt scientifically meritorious manifestations.

## Conceptual Model Specification for Increasing Productivity and Reducing Methane Emission from Paddy Fields

### *Specification from Sulphur Cycle*

In order to fulfil the need of reduction of methane emission from the paddy field and enhance productivity, it is necessary to create condition in paddy culture to let the sulphur cycle follow aerobic path for decomposition of cellulose and convene aerobic decomposition of organics. As revealed by the biochemical reactions of sulphur cycle aerobic reaction will produce sulphate which will get absorbed by the plants for promoting plant structure and functions. When anaerobic decomposition takes place un-desirable production of sulphide and in turn hydrogen sulphide will occur. Under the aerobic decomposition organics will get decomposed $CO_2$ and energy will be produced. Both the bi-products will be useful to crops to some extent. The $CO_2$ causes only one twentieth of warming in contrast with the methane.

### *Specifications from Nitrogen Cycle*

Leguminous crops are known to fix atmospheric nitrogen through their nodulation. In wet paddy field Azolla is known species to fix the nitrogen. Although the pulses grow in upland areas, their contribution to nitrogen fixation can be easily promoted in field when paddy is grown in upland condition or during other season of the year. This is possible when application of fresh or reactivated charcoal one considers cropping system and crop rotation. Details of such manifest-ation are available in **Yadav (2012) and Yadav et al., (2013**). Some studies established that at tillering and flowering root exudations produce maximum methane. At the times of tillering and flowering paddy requires more water. So draining of paddy fields will not be suitable practice for the sake of control of

methane, specially, when rainfall is getting scarce and erratic due to effect of global warming. It requires some methane emission suppressing control measure should be by broadcasting in submerged paddy field.

***Specifications from Adsorption and Absorption Principle***

The charcoal will absorb the methane. There has been some scientific indication of advantage of charcoal application for horticultural trees or crops. Thus, there seems no danger of charcoal in paddy field. Being carbon, it should improve decomposition of organic matter in paddy field by balancing C/N ratio. However, this treatment will involve some expenditure. Carbon trading could come to risk and reduce the cost burden. It will require accurate estimate and getting in to process of carbon trading. In the present study charcoal manifestation was devised to absorb the methane dissolved in water due to ebullition or diffusion before it appears at the water surface to leave the paddy field. This will be an intermittently applicable treatment; therefore, it should be applied when the emission of methane is going to be at the peak rate.

## Model Application Results

Production of sulphate will supplement sulphur requirement of paddy soils. There will be no compulsions of applying sulphate containing ferilisers such as ammonium sulphate and gypsum. Studies have reported that for good yields of paddy submergence, nutrient supply and oxygen diffusion in soil and water should be convened **(Table 3)**. Earlier study by this researcher (**Yadav, 2012**) contained various manifestations for convening aerobic decomposition. The dried crop tissues and organic manner should be decomposed by aerated composting, NADEP composting in India. The green manuring of cow pea and *Sisbania rostera* should be carried out by NADEPED GREEN manuring (NGM) in order to reduce accumulating burden of methane that is excessively built by green manuring in paddy fields. Detailed process and resulting advantages of the NGM are described in **Yadav (2012)**. Now there is need to devise some manifestation to keep the aerobic sulphur cycle to prevail during the growing period of paddy. The resulting sulphate will promote nitrogen, phosphorus and potash uptake by the plants. The sulphate becomes available from the aerobic decomposition of dried plant tissues. The municipal wastewater disposal systems carryout wastewater treatment largely up to secondary treatment. The organic solid wastes are stabilized and water biological treatment completed by trickling filter or prolonged retention in facultative and maturation ponds' technology. Raising algae or rearing fish in the facultative pond has also been found beneficial. Wastewater containing nitrogen and phosphorus are released in the natural water streams that promote eutrophication of the lakes and other stagnant water bodies. The anaerobic (pre) treatment of concentrated wastes of N,P,K are extracted and applied directly to the field crops (**van Lier et al. 2011**). Land disposal is one of simple disposal methods of waste water treated up to secondary stage (**Davis and Cornwell, 1997**). Earlier study (**Yadav, 2012)** suggested innovative improvement in two well known practices of paddy culture ie System of Rice Intensification (SRI) developed in Madagascar **(Web site**) and Raised Bed Cultivation (RBC). Both the practices were suggested to employ organic and cellulose tissues decomposition by NADEP composting. These practices would be ideal for reducing methane emission and enhancing crop productivity of paddy fields. These measures will facilitate other difficulties of paddy culture. Devising suitable cropping pattern and crop rotations will make the paddy based cropping pattern remunerative as crop residue when aerobic decomposition process will produce sulphate that will get utilized by the sulphur loving crop and nitrogen buildup by other environmental principle of resources conservation ie nitrogen cycle. The crop rotation will, to some extent, fix nitrogen from the atmospheric nitrogen gas by cyno- bacteria **(Yadav et al., 2013**). Applying the scientific fact of sulphur cycle, nitrogen cycle and adsorption and absorption of environmental engineering, components of paddy culture were devised for universal applications. In order to make the culture applicable for any given environment and socio economic condition, a numerical value of 100 is assigned for each component of the paddy culture. This situation permits some customization of the paddy culture that may be carried out keeping the franchise of package devised in this study. The customization may be for crop variety, cropping pattern, soil of the region, use of implements and machineries for specific operation, field bed formation, puddling, irrigation, harvesting, following crop cultivation practice and post harvest cultivation of paddy fields, ploughing, nursery raising, planting, irrigation, plant protection measures and other methane eradicative measures for reducing emissions and enhancing yield of paddy fields. In order to carry out the specialized jobs of paddy culture there is need

to promote peoples' participation. Further, it may be necessary to create Business Process Outsourcing (BPO) in paddy cultivating regions. The BPO will serve as extension promotion agents for popularization of specialized works in paddy cultivation. The approach is to produce technology of paddy culture for methane emission reduction and enhance yields of paddy fields.

TABLE 3 AN INNOVATIVE UNIVERSALLY APPLICABLE ZERO METHANE EMISSION AND MAXIMUM YIELD PADDY BASED CROPPING SYSTEM - PADDY CULTURE

| S.No | Work component | Specialised culture component to fulfil objective | Supporting remarks | Assigned weight* |
|---|---|---|---|---|
| 1 | **Cropping system** | Cropping systems should be able to take advantages of scientific facts in agriculture | Paddy onion-and cowpea was found the best cropping system in Indogangetic plain of west Bengal , Acharya et al 2008 | 100 |
| 2 | **Crop variety** | Select hybrid paddy dwarf variety that does not lodge due to excessive growth | Root exudation is known to cause methane emission and yield loss as certain proportion of biomass gets utilized in root exudation. Phosphorus deficiency promotes root exudation that leads to methane emission. | 100 |
| 3 | **Nursery raising.** | In order to convene aerobic action the nursery raising should be on raised bed irrigated by low pressure mist blowing irrigation | The nursery time emission will get reduced due to elimination of submergence for prolonged time. | 100 |
| 4 | **Manure** | Apply organic manure to supplement 25 % of N by NADED compost and plouwdow down 20 days prior to transplanting | Aerobic decomposition will emit $CO_2$ in place of Methane | 100 |
| 5 | **Green manuring** | Carry out Nadeped green manuring to enhance cropping system productivity of paddy field | Yadav 2012 described the advantages of NGM and reduction of methane. | 100 |
| 6 | **Transplanting** | Transplant paddy in bedded field to have field saturated, not submerged to eliminate anaerobic decomposition. | Aerobic decomposition will form sulphate that will be taken by the plants for promoting gorwth and plant function (Sulphur cycle fact) | 100 |
| 7 | **Weeding** | Carry out weeding in early morning or late evening to have low rate of methane emission | Do not leave the weeded material in the field to avoid sulphide formation that is injurious to plants. | 100 |
| 8 | **Mulching** | Do not apply mulch for the sake of water conservation and nutrient particularly N supply as it will cause sulphide buildup | Refer sulphur cycle. Sulphate built by the compost etc will suffice need of extra sulphate containing fertilizers. | 100 |
| 9 | **Puddling** | In case the paddy field is likely to have unavoidable continuous submergence for more than a week carry out puddling and create some raised bed exposure to promote oxygen diffusion to soil.. | Creation of puddling for creating hard impermeable layer may not be necessary unless proven by sufficient research evaluation | 100 |
| 10 | **Methane absorbing treatment** | Spread to the extent possible in paddy water activated charcoal to absorb the methane dissolved in water or that will get out from soil by ebulation. | This treatment is devised as per application of scientific fact of absorption by charcoal of toxic cases in environmental engineering. | 100 |
| 11 | **Eradicate excess $CO_2$.** | Carry out *Geoact Ca-5* for reducing $CO_2$ burden in atmosphere | Reference, Yadav 2012 | 100 |
| 12 | **Stop irrigation before harvest date** | The field should get ploughed down by soil turning plough to cover residue by friable soil to convene aerobic decomposition. | Do not go foe zero tillage or burn residue as there will be release of methane under both the condition of paddy culture(Yadav and Srivastava, 2009) | 100 |
| 13 | **Plant onion or wheat** | These crops utilize sulphate built by aerobic decomposition of paddy residue incorporated by ploughing | Any crop planted with zero tillage will not bring residue under aerobic condition and development of soil cracks will permit methane release from the paddy field. There may be need for extra sulphate containing fertilizer application | 100 |
| 14 | **Apply nitrogen cycle** | For application of scientific facts of nitrogen cycle carryout summer cropping of cow pea for cynobacteria activity for nitrogen build-up | Water for irrigation for summer cropping and protection of crop from wild animals may be problem. | 100 |
| 15 | **Apply scientific fact of N cycle** | Green manuring of sunhemp, sisbania, and indigo should be sown in May and allow to grow till one week prior to field preparation and transplanting. | Harvest biomass for NADEP composting for aerobic decomposition. | 100 |
| | | **Total score** | | **1500** |

*The weighting factors are given equal value because as all of them are equally important for an ideal prescription of paddy culture to bring zero methane emission and increase paddy yield. The score of the customization of the paddy culture in a region will reflect the success of customized application.

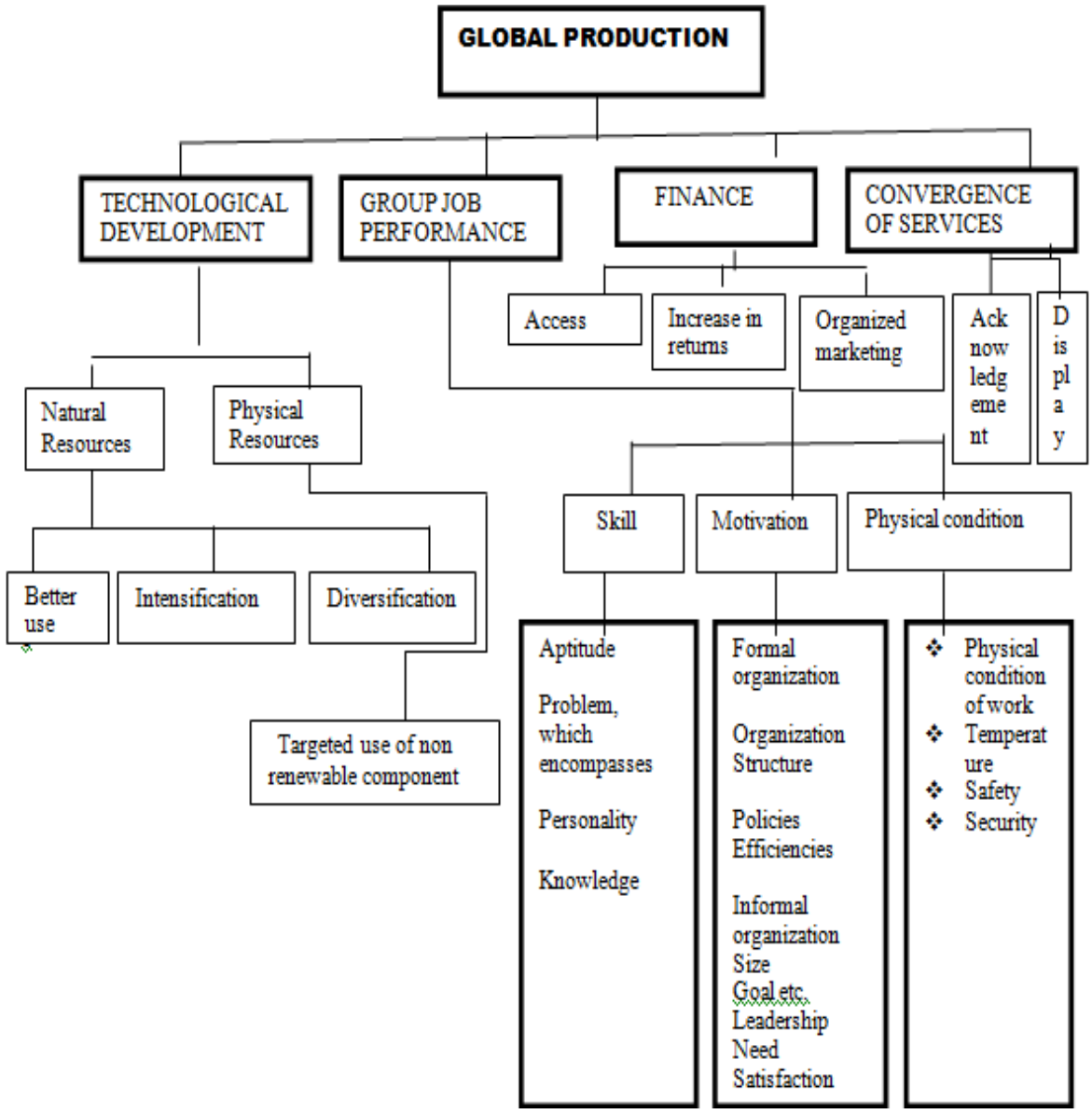


FIG. 2 FACTORS OF GLOBAL PRODUCTIVITY AS APPLICABLE FOR REDUCTION OF EMISSION OF METHANE FROM AND ENHANCEMENT OF PRODUCTIVITY OF PADDY FIELDS

## Global Production

The efforts were made to conduct researches to understand process and chemistry that operates in the paddy fields. Experimental finding to verify and refine methane emissions estimates have indicated reductions in methane release because of estimate refinement and measurement with availability of precise instrument-ations etc. However, since there was no manifestation, there could not be any effort to reduce methane emission from the paddy field by direct or indirect means. Thus, the results of heavy expenditures could not come to reduce burden of methane emission in to atmosphere. The expected yield increases remained visible specific to the research site. Thus, the valuable three decades passed and paddy cultivation bore curse of releasing high proportion of methane. The time loss was on the account of the search of perfect technology.

In the present study situation of technology developments was brought to a level that it can be applied to paddy fields for achieving both the functions namely reduction of methane release and increase in productivity of paddy fields by making better use of the natural resources or the resources already invested on paddy cultivation (**Table 3).** While the refinement will be coming up in future, there is need to apply the ready knowledge and package of practice of paddy culture to produce paddy and reduce burden of methane release.

The global production can be achieved by application of technology, group job performance, finance and

convergence of services as depicted by **Fig. 2**. The technology sufficiency was dealt sufficiently as above, the group jobs are to be looked at.

The group job performance another arm of increasing productivity has to be promoted equally well. This can be achieved by applications of the paddy package on paddy fields globally to produce food and reduce methane burden to the atmosphere.

There are certain jobs which cannot be performed by any individual alone. It requires peoples' participation in give and take mode. Since it is agriculture, where GDP contribution is low at national scale, paddy cultivation was taken as indicator of poverty. Major proportion of paddy cultivators are technology ignorant and resources poor farmers. They have low ability, due to variety of factors, lack of formal and informal institutional support, need motivation and creation of good environment. The environment of paddy cultivation is equally inconducive ie, muddy, hard, laborious and manpower involving. In this study the development of BPO has been suggested that will work as motivation promotional agency for paddy cultivation.

The finance required has to be managed by the finance institutions to the tune of ongoing expenditure. The other functions of the financial institutions are access, increase in returns and organized marketing. Due to increase in productivity increase in return is bound to come. Further, when the resources are scientifically managed, the food quality is likely to develop and organized marketing will pass on some proportion of the profits to the growers. In order to bring field applications and technology refinements the practices are to be brought by convergence of the services of plant protection, other crop promotion, dairy, agro forestry, fishery, piggery and bee keeping etc to supplement the paddy production. Thus, there is need to apply thrust on global production to make substantial gains in reduction in methane release and food production.

## Follow up action

As evident from 15 items listed in **Table 3** there are some kinds of follow up action required for each of the items. The follow up action has to be carried out by imparting knowledge and operation management program for seasons forecast, basic material availability, seed, and fertiliser, harvesting, threshing and drying of the produce. Value addition and market infrastructure of road and *mandies, organised marketing places)* etc to be created. It should not be construed that this will be the first action in this sector, but when production will increase it is obvious that other facilities should also be extended in same proportion so as to not let the produce go waste for the sake of processing and marketing.

The follow up action should support technology knowledge by imparting and assessment of adoption by Roger's diffusion of innovation (DOI) applied in various fields **(Yadav et al., 2012)** and on the peoples' group job performance. Such type of follow-up actions were described for land conservation works (**Yadav and Bhushan, 2002**).

## SWOT Analysis

### *Strength*

Paddy cultivation is prominent practice, but operationally difficult to carry out, to feed almost 50 % of total population of the world. It requires excessive amount of water. Main season of paddy cultivation is rainy season. In order to supplement food, in many areas two to three crops of paddy are raised. Low lying areas and rainy season paddy are cultivated with submergence in the field. Up land paddy or off season paddy also are given submerged irrigation, therefore, they also suffer temporarily anaerobic decomposition. Due to the build-up of green house gases the atmosphere has been chocked with excessive volume of methane that has lead to the problem of global warming. Intensive rice cultivation comprise crops, cropping practices, cultivation operation and adverse effect of environment. This situation has demanded to devote concern to understand the problems associated with paddy culture and find cause effect results to bring improvement in the paddy culture to ease out the worsening situation. In this domain, lot of efforts, finance, resources and labourers have gone to generate lessons for improvements in future developments.

There have been set of scientific practices which have strong bearing on the practices constituting the paddy culture. Review of the literatures has revealed results, but, in many cases the real scientific reason to explain the fact have not emerged, under most of situation the knowledge resulted in black box situation. The scientific reasons which could not be explained by the research groups could be very well explained when the scientific facts are applied to the situation. These facts have been verified by using the researches published in literature. Review literature for published works of past three decades and more were utilized to substantiate the findings of lack of

knowledge in application of scientific fact.

The no application of scientific knowledge culminated in taking stakes by the researchers to explain that paddy culture had lot of variation resulting in the name of affects of soil, climate and socio-economic factors. Such fact based practices gave genesis for getting blame of highest methane contribution by the paddy fields. The blame and pressure from the developed countries was to reduce paddy cultivation, which is difficult to come in order to cope up with the increasing food demands. There has been concern to reduce the bad effect of paddy culture. However, there has been hardly any universally applicable paddy productive and environment friendly development.

This study had taken as challenge to come up with some innovation by applying appropriate scientific facts. A paddy culture prescription was devised by innovative applications of the scientific facts. These components of practice are scientifically correct and experimentally verified by using results of studies available. Hence, there is no doubt on the working and application of the practices that displays enormous strength of this technology. The prescription comprises right from cropping system for year round cultivation for its crop diversification, in lieu of paddy after paddy, so as to make land, water, environment, people and society benefited. Atmosphere gets free of methane emission burden.

The factors entering in the paddy culture are assigned equal weightage as under variable situation different factors may be prominent. The deviation from the total score will depict discrepancy in the paddy culture due to limitations imposed by site, region and socio-economic status.

### *Weakness*

As such there is now weakness in the study. All scientific facts of well known principles are used to fulfil the objectives of the study and devising the manifestation of practices that constitute the paddy culture for zero methane emission and increased productivities. The weakness of science of agriculture of paddy cultivations have been removed and scientifically correct practices which contribute to reduction of methane emission and promote productivity are included in the prescription. However, one can consider the operational limitation of application of the practices, the required operation have been suggested to be carried out by peoples participation (**Yadav 2013**).

Further provision is made to create BPO in conducting paddy culture. These BPOs will gain experience and acquire tools and plants, trained manpower team to implement the specialized task. The BPOs will work as paddy culture promotional agency and reduce burden of agricultural extension to spread the concept. There is no weakness of extra demand of resources, albeit, the prescribed paddy culture will make better use of resources land, water, plant, environment, people and waste materials in producing best result to promote paddy productivity and conserve environment. Reduction in methane emission will lead to reduction in global warming which is the need of the present century. It does not demand extra fund or resources and is capable to produce benefit right from the day one it is implemented. Although increase in yield will come in three to four months but the reduction in methane emission necessary to curb global warming start from the day it is adopted.

Although the components of the zero emission paddy culture are sufficiently verified, it will be necessary to carry out studies on optimization of factors identified under generation II (2G) to bring further refinement under generation II (2G).

### *Opportunity*

The study has created an opportunity of agriculture sector that contributes almost 50 % of food supplement for the global population. It has opened frontier to reduce emission of methane. **Wassmann et al., (2009)** while defending the water saving by the appropriate water management in the rice field feared that water saved will be further used for cultivating additional hectarage of rice that will further enhance building up of methane in the atmosphere. Present research has capability to eliminate this danger of further building of methane in the atmosphere as the practice will enable diversification in agriculture and the technology by itself eliminates methane emission from the paddy field as a result of innovative application of the scientific fact. This is a real solution to the problem of built up of methane burden in to the atmosphere. Thus, this technology has fulfilled and accomplished the solution to global problem methane accumulation in the atmosphere and global warming leading to climate change.

It has also enabled to make best use of resources of waste materials such as residue, dung, wastes driven from waste water and sewage streams to improve

agriculture at the same time create clean and green environment (**Yadav, 2012**). It has created peoples participation for handling works that require extra manpower on give and take basis. Such peoples' participation will bring coherence in the society. Creation of BPO is an attempt to increase employment in agriculture sector as well as services. The goods remain with the owners, the service should thrive and produce employment for low middle, and high level educated people, like in other service sectors. There is opportunity to control severe price rise of food materials. Shortage of food was found as a cause for violence in many countries in recent years. Sufficiency in food will satisfy primary need which can not otherwise be suppressed. When primary need is satisfied other secondary needs can be moderated to create stability in the world.

Since it is the study of second generation (2G) optimization will lead to still better refinement of paddy culture prescription in time to come. The specialized tasks such as, soil turning ploughs, harrows, seed drills, paddy transplanters, weeders, puddlers, ridgers, harvesters, sprinklers, plant protection equipments, spraying and charcoal and $CO_2$ eradication equipment will demand industrial development. Better than present use of limited resources of land, water, nutrient will produce sufficient better quality food that will promote good health of people due to nutritious foods. The reduction in methane load will improve environmental condition conducive to better living. It will bring real social good in regions, countries and globe.

### *Threat*

As brought out earlier there was no weakness, in the same way, there is no threat to development induced by the results of this study. However, with large production of rice the price of the food will get stabilized. Stability will desirably discourage speculative and black marketing in food sector. This fact can be converted in strength of the society and the government. The further threat can be expected as it has happened in history that with the development of prosperity, many bad habits of getting lazy, resorting to drinking and sex related diseases may also flourish. These are natural developmental phenomena and there will be several other cures hence such speculative threats should not be taken to discourage the universally applicable paddy culture devised in this study.

## Conclusion

The review of past development, successes and failures were taken to substantiate and derive verifications of the scientific facts. The results lead to substantiation of the gap of scientific knowledge in paddy culture. High concentration of methane has been accepted as cause for global warming. The pressurize reduction of paddy cultivation could not develop, but it demanded intensification to fulfil food demand of the global population. Resulting need of intensification of paddy cultivation has been fulfilled by devising universally innovative application of scientific facts of sulphur cycle, nitrogen cycle and environmental engineering principle of absorption of toxic gases from the paddy field. The faulty situations have been convened for betterment for reducing methane emission and increasing paddy field productivity. A paddy culture package was devised to create zero emission of methane, improve land, water, nutrient, fertilized; resources use efficiency for increasing food production. The crux of the development was to convene aerobic decomposition of organics and cellulose etc. for producing sulphate taken up by paddy crops. Many associated components are prescribed to fulfil the objective of reducing emission of methane and promoting productivity. No need was felt to carry out study on mulching or nutrient supplementation by the mulching of organic and cellulose material as it is sufficiently established that they cause more harm than good to the paddy plants under submerged condition. It is recommended to carryout research studies on optimization of factors of prescribed paddy culture as generation II (2G) agriculture. Some areas of research for generation II (2G) agriculture are chalked out for refinement of all component of the paddy culture.

- Study of factor of optimization will further save research time, research fund, resources and produce early results for field applications. Good food sufficiency, liveable environment and coherent society and stable government support development for building liveable world.
- Carryout studies on year round productivity of scientifically designed cropping system to establish most productive system. In order to make the better use of natural resources of functioning of sulphur and nitrogen cycles, cultivate only rainy season crop and adopt diversification. In this way practice of *boro* (winter season rice crop in India) rice should be

discontinued.

- Screen dwarf hybrid paddy varieties for no lodging, low root exudation and high yield with rain, irrigation and sewage water irrigation.
- Strengthen research on microbiology to produce efficient sulphate producing bacteria from cellulose and waste materials.

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